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RESEARCH MEMORANDUM

MEASUREMENTS OF PRESSURE DROP WITH NO HEAT ADDITION ON MOCKUP SEGMENTS OF THE GENERAL ELECTRIC AIR-COOLED AIRCRAFT REACTOR

By Eldon W. Sams and Tibor F. Nagey

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An investigation was conducted at the NACA Lewis laboratory to obtain pressure-drop data for flow of air with no heat addition through mockups of two reactor segments of the proposed General Electric Company aircraft reactor. Pressure-drop data were obtained over a range of Reynolds numbers from 4000 to 80,000, air inlet Mach numbers from 0.02 to 0.40, inlet pressures up to about 40 inches of mercury absolute, and ambient air temperatures. The results indicate that the friction factors, corrected for entrance, vena contracta, momentum, and exit losses, are considerably higher at the high Reynolds numbers than those reported for turbulent flow in smooth pipes.

INTRODUCTION

An air-cooled reactor is being built by the General Electric Company for aircraft propulsion. The proposed reactor is a right circular cylinder approximately 5 feet in diameter and 3 feet long, with cooling air passing axially through the reactor. Axially, the reactor is composed of ten segments, each 3.5 inches long, with an axial spacing of 0.125 inches between segments. Each reactor segment is composed of a series of concentric rings between which are sandwiched triangular passages. The cooling air flows axially through these triangular passages and is allowed to expand into the 0.125-inch spacing between segments before flowing through the next annular segments. The equivalent diameter of each passage is varied axially. The material forming the concentric rings and the triangular passages is a stainless-steel-clad uranium oxide core, the thickness of the sandwich being approximately 0.012 inch.

In view of the complex geometry of the air-flow passages, prediction of the air pressure drop in the reactor from data available in the literature is difficult. In order to gain some insight into the pressure-drop characteristics of the reactor, mockups of small portions of the fifth and tenth annular reactor segments were tested by the NACA Lewis laboratory. These test sections were made of aluminum and were supplied by the General Electric Company.

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The tests were conducted over a range of inlet Mach numbers from about 0.02 to 0.40 with inlet pressures up to about 40 inches of mercury absolute at ambient air temperature. The range of Reynolds numbers investigated was from about 4000 to 80,000 for each of the test sections. The results of these tests are presented herein in the form of curves of average half-friction factor plotted against Reynolds number for each of the test segments. Both measured and calculated data are also presented in tabular form.

EQUIPMENT AND INTRUMENTATION

Reactor segments. - Two reactor segments, number 5 and number 10 in axial spacing of the complete reactor, were tested; both were fabricated of 0.012-inch sheet aluminum. Figure 1(a) shows, segment number 5, which had five rows of triangular passages, and figure 1(b) shows segment number 10, which had six rows of triangular passages.

Pertinent geometrical charactersitics for the two segments are presented in the following table:

Reactor segment number	Length (in.)	Width (in.)	Height (in.)	Equivalent diameter (ft)	Length to diameter ratio L/D_e	Free flow area (sq ft)	Free-flow factor
5	3.5	3	2	0.0208	14.0	0.0385	0.92
10	3.5	3	2	0.0201	14.45	0.0386	0.90

Air system. - A schematic diagram of the test section and experimental setup used in this investigation is shown in figure 2. Figure 2(a) shows the general piping layout. Service air at 110 pounds per square inch gage is passed through a filter, through a pressure-regulating valve, and then through an orifice run, consisting of an air straightener and an A.S.M.E.-type flat-plate orifice where the air flow is measured before entering the inlet tank. From the inlet tank, the air flows through the test section and is discharged to atmosphere. The orifice and test-section inlet-air temperature is measured by a thermocouple just downstream of the orifice plate.

Test-section instrumentation. - The reactor segment was mounted in a rectangular wood duct provided with a rounded entrance section. Three static pressure taps were located in the wood duct at both the entrance section and the exit section as shown in figure 2(b); one tap was located at the bottom and one tap on each side of the duct at both sections. The static pressure drop was taken as the difference between the average inlet and the average outlet measured static pressures. In several cases, as a check on the instrumentation, the static pressure drop was obtained by the use of a micromanometer connected directly across one inlet and one outlet tap. These pressure drops were in good agreement with the average pressure drops.

In figure 3 are photographs of segment number 5 mounted in the wood duct, showing the rounded section and the relative location of the three inlet static pressure taps.

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SYMBOLS

The following symbols are used in this report:

A	free-flow area, sq ft
D_e	effective diameter of reactor segment, 4A/P, ft
F	free-flow factor (free-flow area/total frontal area)
$(f/2)'$	average half-friction factor corrected for momentum loss
$(f/2)''$	average half-friction factor corrected for entrance, exit, vena-contracta, and momentum losses
G	mass velocity (mass flow per unit cross-sectional free flow area), $\left(\frac{W}{A}\right)$, lb/(sec)(sq ft)
g	acceleration due to gravity, 32.2 ft/sec^2
K_c	vena-contracta pressure-loss coefficient
L	length of reactor segment, ft
P	wetted perimeter of reactor segment, ft
p	static pressure, lb/sq ft
$\Delta p'$	measured pressure drop corrected for momentum loss, lb/sq ft
$\Delta p''$	measured pressure drop corrected for entrance, exit, vena contracta, and momentum losses, lb/sq ft
Δp_{meas}	over-all measured static pressure drop across reactor segment, lb/sq ft

Δp_{en} entrance pressure drop, lb/sq ft

Δp_{ex} exit pressure drop, lb/sq ft

Δp_m momentum pressure drop, lb/sq ft

Δp_{vc} vena-contracta pressure drop, lb/sq ft

R gas constant for air, 53.35 ft-lb/(lb)($^{\circ}$F)

Re Reynolds number, D_eG/μ 2615

t static temperature at entrance of test section (inlet-air temperature), $^{\circ}$R

Δt static temperature difference between entrance and exit of test section (taken as zero for these tests), $^{\circ}$R

V velocity, ft/sec

W air flow, lb/sec

α $\Delta p/p_1$

β $\Delta t/t_1$

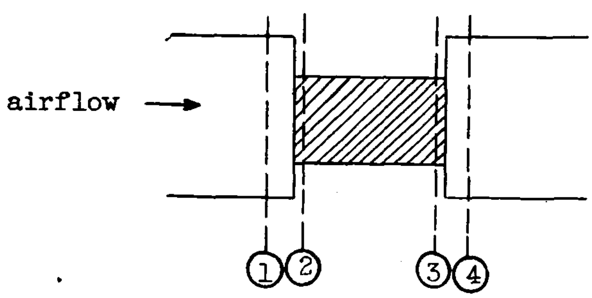
μ absolute viscosity of air, lb/sec-ft

ρ air density, lb/cu ft

τ_0 shearing stress defined as average friction force per unit area

Subscripts

The following diagrammatic sketch of the test section defines the subscripts pertaining to the various stations



RESULTS AND DISCUSSION

All the pertinent measured and calculated data presented in figures 4 and 5 are tabulated in tables I(a) and I(b). Values for entrance loss and exit pressure recovery are not tabulated, inasmuch as they were about the same order of magnitude.

Friction factors based on measured over-all static pressure drop corrected for momentum loss. - The average half-friction factors obtained
2615 for reactor segments 5 and 10 are shown in figure 4, where the average half-friction factor corrected for momentum pressure loss $(f/2)'$ is plotted against Reynolds number D_eG/μ. The average half-friction factor $(f/2)'$ is based on the measured over-all static pressure drop corrected for momentum pressure loss as given in the following equation:

$$(f/2)' = \frac{\Delta p'}{8\ L/D_e} \frac{1}{\rho V^2/2g}$$

where

$$\Delta p' = \Delta p_{meas} - \Delta p_m$$

and

$$\Delta p_m = \frac{G_2{}^2}{g\rho_1}\left(\frac{\beta+\alpha}{1-\alpha}\right)$$

These equations and subsequent equations are derived in appendix A and a sample calculation is shown in appendix B. The units required are given in the section of the report entitled "Symbols".

Included in the figure, for comparison, is the von Karman-Nikuradse line (solid), representing the relation between friction factor and Reynolds number for turbulent flow in smooth pipes, the equation of which is:

$$\frac{1}{\sqrt{8\ f/2}} = 2\ \log\left(\frac{D_eG}{\mu}\sqrt{8\ f/2}\right) -0.8$$

The dashed line, in the figure, represents the half-friction factor relation in the laminar region, the equation of which is:

$$\frac{f}{2} = 8\left(\frac{D_eG}{\mu}\right)^{-1.0}$$

The data for reactor segments 5 and 10 are not in agreement with the reference line for turbulent flow in smooth pipes; the friction factors for both reactor segments are higher than those for smooth pipes. The friction-factor data for each segment can, however, be well represented by a single line, the data falling within ±5 percent of a mean line through the data for each reactor segment. Check points were obtained for both reactor segments and, as shown in the figure, indicate good reproducibility of the data. At the highest Reynolds number obtained (about 70,000), the friction factors for segments 5 and 10 are higher by about 44 and 110 percent, respectively, than those given by the von Karman-Nikuradse line for smooth pipes.

Friction factors based on corrected pressure drops. - The average half-friction factors for reactor segments 5 and 10 are presented in figure 5 with the same coordinates as used in figure 4. In this case, 2615
however, the average half-friction factors $(f/2)''$ are based on measured over-all static pressure drops which were corrected for entrance, vena-contracta, momentum, and exit pressure losses as given in the following equations:

$$(f/2)'' = \frac{\Delta p''}{8\ L/D_e} \frac{1}{\rho V^2/2g} \tag{5}$$

where

$$\Delta p'' = \Delta p_{meas} - (\Delta p_{en} + \Delta p_{vc} + \Delta p_m + \Delta p_{ex})$$

and

$$\Delta p_{en} = \frac{{G_2}^2}{2g\rho_1}(1-F^2) \tag{6}$$

$$\Delta p_{vc} = K_c \frac{{G_2}^2}{2g\rho_1}$$

$$\Delta p_{ex} = \frac{{G_1}^2}{g\rho_1}\left(\frac{1+\beta}{1-\alpha}\right)\left(1 - 1/F\right) \tag{8}$$

No pressure-loss correction was applied for velocity profile development. Both reactor segments had an L/D_e of approximately 14, which might be too short a length to cause a full profile development. Rather than assume a full or some partially developed profile, this correction was not included in the calculations.

For the data reported herein, the use of the inlet air density in place of air average density introduced no significant error. In cases where there would be heat addition in the reactor segment or longer sections of greater pressure drop, the calculations should be based on an average or some weighted air density.

As in figure 4, the friction factors for both segments 5 and 10 fall above the reference line. The corrections applied, however, tend to cause the data for both reactor segments to approach the reference line. In this case, the data for segments 5 and 10 are higher by about 26 and 95 percent than those given by the von Karman-Nikuradse line at a Reynolds number of about 70,000.

Although the friction factors are somewhat higher than the reference line, the slope of the data for both segments is essentially that of the
2615 reference line at Reynolds numbers below 10,000; at Reynolds numbers greater than 10,000, the slope becomes appreciably less than that for the smooth-pipe line.

SUMMARY OF RESULTS

The results of tests to obtain air-pressure-drop data with no heat addition on two reactor segments of a proposed aircraft air-cooled reactor can be summarized as follows:

1. The measured average half-friction factors (corrected only for momentum) obtained for each reactor segment can be well represented by a single line throughout the range of Reynolds numbers investigated. However, the lines are not in agreement in magnitude or slope with the von Karman-Nikuradse reference line representing turbulent flow in smooth pipes. The slopes of the lines through the data are essentially the same as the reference line at Reynolds numbers below 10,000, but become considerably less at the higher Reynolds numbers. The friction factors for segments 5 and 10 are higher than the reference line by about 44 and 110 percent, respectively, at a Reynolds number of about 70,000.

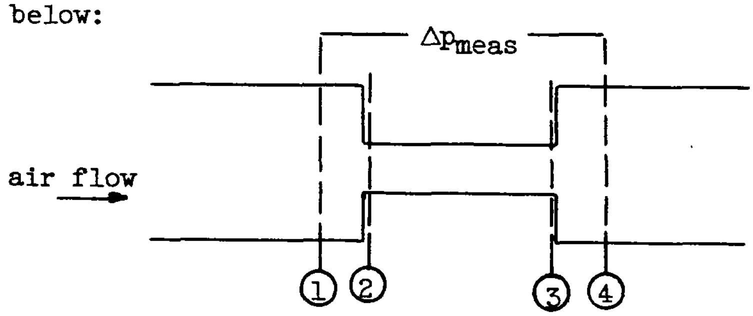
2. Correction of the measured pressure drop for momentum, entrance, exit, and vena-contracta losses tends to bring the friction factor for both segments nearer to the reference line. However, the slope of the lines at the higher Reynolds numbers is still appreciably less than that for the smooth-pipe line. The corrected friction factors for segments 5 and 10 are higher than the reference line by about 26 and 95 percent, respectively, at a Reynolds number of about 70,000.

3. The displacement of the curves above the reference line would indicate that some re-evaluation of the effective diameter, or inclusion of other parameters pertinent to the geometry of the segment would be required for correlation of the data for both segments.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, August 24, 1952

APPENDIX A - DERIVATION OF THE PRESSURE DROP EQUATIONS

A schematic diagram of the test section showing the various stations is given below:



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The friction factor can be defined by the following general equation:

$$f = \frac{\tau_0}{\frac{1}{2}\frac{\rho V^2}{g}} \tag{1}$$

where τ_0 is the shearing stress defined as the average friction force per unit area.

Equation (1) can also be written as:

$$(f/2)'' = \frac{\Delta p''}{8\ L/D_e\ \rho V^2/2g} = \frac{\Delta p''}{8\ L/D_e\ G^2/2g\rho} \tag{2}$$

The following equation defines the $\Delta p''$ of equation (2)

$$\Delta p'' = \left\{(\Delta p_{meas}) - \left[\Delta p_{en} + \Delta p_{vc} + \Delta p_m + \Delta p_{ex}\right]\right\} \tag{3}$$

The friction factor as calculated by equations (2) and (3) does not represent the exact value of the ratio of the shearing stress at the wall to the dynamic pressure of the stream, inasmuch as no pressure-loss correction was applied to equation (3) to account for velocity profile development. The reactor segments tested had an L/D_e of approximately 14, which were felt to be too short a length for full profile development. Rather than assume a full or some partially developed profile, this correction was not applied in the calculations.

The various terms of equation (3) are derived as follows:

[redacted]

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Entrance pressure loss, Δp_{en}. - Losses of mechanical energy occur in the flow stream in the region of contraction from station (1) to (2). The general energy equation between these stations can be written:

$$p_1 + \frac{\rho_1 V_1^2}{2g} = p_2 + \frac{\rho_2 V_2^2}{2g} \tag{4}$$

Assuming no friction and incompressibility of the fluid, the following relations apply:

$$\rho_1 = \rho_2$$

and

$$V_2 = \frac{A_1}{A_2} V_1$$

Hence,

$$\Delta p_{en} = p_1 - p_2 = \frac{\rho_1 V_1^2}{2g}\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right) \tag{5}$$

where A_2/A_1 is defined as the free-flow factor F, and rewriting equation (5) in terms of mass velocity in the test section results in:

$$\Delta p_{en} = p_1 - p_2 = \frac{G_2^2}{2g\rho_1}\,(1-F^2) \tag{6}$$

Exit regain Δp_{ex}. - The momentum change between stations (3) and (4) where an expansion occurs can be stated as follows:

$$\frac{W}{g} V_3 + p_3\, A_4 = \frac{W}{g} V_4 + p_4\, A_4 \tag{7}$$

Assuming incompressibility, equation (7) can be written as:

$$p_3 - p_4 = \Delta p_{ex} = \frac{\rho_3 V_3^2}{g}\left[\left(\frac{A_3}{A_4}\right)^2 - \left(\frac{A_3}{A_4}\right)\right] \tag{8}$$

As before, $A_2/A_1 = F$ and $A_3/A_4 = F$; therefore,

[redacted]

$$\Delta p_{ex} = \frac{G_3{}^2}{g\rho_3}\left[F^2 - F\right] \tag{9}$$

In order to write equation (9) in terms of entrance conditions at station (1) the following was assumed:

$$\rho_3 = \frac{p_3}{Rt_3} = \frac{p_1 - \Delta p}{R(t_1+\Delta t)} \tag{10}$$

In this case the Δp used in equation (10) is an approximation in that the value for Δp_{meas} was used in order to avoid a trial-and-error solution. The error incurred by this assumption is negligible.

Equation (9) can be rewritten with the aid of equation (10) as follows:

$$\Delta p_{ex} = p_3 - p_4 = \frac{G_1{}^2}{g\rho_1}\left(\frac{1+\beta}{1-\alpha}\right)(1 - 1/F) \tag{11}$$

where

$$\alpha = \Delta p/p_1 \tag{12}$$

and

$$\beta = \Delta t/t_1 \tag{13}$$

In these particular tests, with no heat addition, β was, of course, always equal to zero.

Vena-contracta pressure loss Δp_{vc}. - The vena-contracta pressure loss was taken as a factor K_c times the velocity head of the stream in the test sections and is given by the following equation:

$$\Delta p_{vc} = K_c \frac{G_2{}^2}{2g\rho_1} \tag{14}$$

where K_c is a function of only the free-flow factor of the test section. Values of K_c are given in reference 1 plotted against free-flow factor.

Momentum pressure loss Δp_m. - Using the general momentum equation and assuming $\rho_1 = \rho_2$ result in the following equation:

$$\Delta p_m = (p_2 - p_3) = \frac{G^2}{g}\left(\frac{1}{\rho_3} - \frac{1}{\rho_1}\right) \tag{15}$$

Rewriting equation (15) by means of equations (10), (12) and (13) gives:

$$\Delta p_m = (p_2 - p_3) = \frac{G_2{}^2}{g\rho_1}\left(\frac{\beta+\alpha}{1-\alpha}\right) \tag{16}$$

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In the calculations just described, the total and static temperatures were assumed to be the same. Several check calculations which were made at the highest flow conditions showed that this assumption gave negligible error. With heat addition and at high flow rates this assumption is obviously not to be expected to remain valid.

APPENDIX B - SAMPLE CALCULATION - RUN NUMBER 1 FOR REACTOR SEGMENT NUMBER 5

Effective diameter, D_e = 0.0208 ft

Free-flow area, A = 0.0385 ft^2

Corrected air flow, W = 1.712 lb/sec = 6162 lb/hr 2615

Absolute viscosity of air, μ(at 506° R) = 0.0426 lb/hr-ft

$$Re = \frac{D_e G}{\mu} = \frac{D_e}{\mu}\frac{W}{A} = \frac{0.0208 \times 6162}{0.0426 \times 0.0385} = 78{,}300$$

Inlet-air temperature = 506° R

Inlet-air pressure = 39.66 in. Hg abs. = 2804 lb/sq ft abs

Free-flow factor, F = 0.92

$$\Delta p_{en} = \frac{G_2^2}{2g\rho_1}(1-F^2) = \frac{\left(\frac{1.712}{0.0385}\right)^2}{64.4 \times 0.104}(1-0.92^2) = 296 \times 0.1536 = 45.5 \text{ lb/sq ft}$$

$$\Delta p_{meas} = 147.7 \text{ lb/sq ft}$$

$$\alpha = \Delta p/p_1 = 147.7/2804 = 0.0527$$

$$\beta = \Delta t/t_1 = 0$$

$$G_1 = G_2 F = 44.46 \times 0.92 = 40.9$$

$$\Delta p_{ex} = \frac{G_1^2}{g\rho_1}\left(\frac{1+\beta}{1-\alpha}\right)\left[1 - \left(\frac{1}{F}\right)\right]$$

$$= \frac{40.9^2}{32.2 \times 0.104}\left(\frac{1+0}{1-0.0527}\right)\left(1 - \frac{1}{0.092}\right) = -46.0 \text{ lb/sq ft}$$

$$\Delta p_{vc} = K_c \times \frac{G_2^2}{2g\rho_1} = 0.05 \times 296 = 14.8 \text{ lb/sq ft}$$

[redacted]

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where $K_c = 0.5$ (from reference 1)

$$\Delta p_m = \frac{G_2^2}{g\rho_1}\left(\frac{\beta+\alpha}{1-\alpha}\right)$$

$$= 2.0 \times 296 \left(\frac{0+0.0527}{1-0.0527}\right) = 32.9 \text{ lb/sq ft}$$

$$\Delta p'' = \Delta p_{meas} - (\Delta p_{en} + \Delta p_{ex} + \Delta p_{vc} + \Delta p_m)$$

$$= 147.7 - (45.5 - 46.0 + 14.8 + 32.9)$$

$$= 100.5 \text{ lb/sq ft}$$

$$\left(\frac{f}{2}\right)'' = \frac{\Delta p''}{8\,\frac{L}{D_e}} \times \frac{1}{\frac{G_2^2}{2g\rho_1}}$$

$$= \frac{100.5}{8 \times 14.0} \times \frac{1}{296} = 0.00303$$

REFERENCE

1. McAdams, William, H.: Heat Transmission. 2nd ed., McGraw-Hill Book Co., Inc., (New York and London), 1942, p. 122.

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TABLE I - MEASURED AND CALCULATED DATA FOR REACTOR SEGMENT ISOTHERMAL PRESSURE DROP TESTS

(a) Reactor segment number 5. Free-flow area, 0.0385 square feet; free-flow factor 0.92; equivalent diameter D_e, 0.0208 feet; length to diameter ratio L/D_e, 14.0.

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Run	Air flow (lb/sec)	Inlet air temperature (°R)	Inlet air pressure (lb/sq ft abs)	Reynolds number	Inlet air Mach number	Measured pressure drop ΔP (lb/sq ft)	Calculated momentum pressure drop ΔP_m (lb/sq ft)	Calculated vena contracta pressure drop ΔP_{vc} (lb/sq ft)	Corrected half-friction factor[a] $(f/2)'$	Corrected half-friction factor[b] $(f/2)''$
1	1.712	506	2804	78,300	0.389	147	32.93	14.81	0.00346	0.00303
2	1.673	516	2768	75,500	.386	144	31.70	14.51	.00347	.00303
3	1.644	508	2732	74,900	.384	140	30.57	14.07	.00350	.00306
4	1.515	514	2659	68,500	.366	119	23.32	12.42	.00345	.00300
5	1.493	508	2632	68,000	.362	117	22.59	12.05	.00353	.00308
6	1.433	507	2573	65,400	.355	110	20.31	11.34	.00354	.00310
7	1.299	512	2514	58,900	.331	92.1	14.65	9.63	.00359	.00314
8	1.283	511	2500	58,300	.328	88.4	13.83	9.42	.00354	.00308
9	1.134	508	2389	51,700	.303	73.2	9.68	7.66	.00371	.00324
10	1.043	516	2369	47,100	.283	63.0	7.25	6.64	.00375	.00328
11	.868	508	2252	39,500	.246	44.5	3.84	4.76	.00382	.00335
12	.834	520	2267	37,400	.237	42.5	3.42	4.47	.00391	.00343
13	.730	510	2254	33,300	.207	31.7	1.93	3.38	.00394	.00345
14	.721	518	2210	32,400	.210	32.2	2.02	3.47	.00396	.00348
15	.689	512	2210	31,200	.200	28.7	1.62	3.08	.00393	.00344
16	.651	512	2213	29,500	.188	26.0	1.31	2.75	.00401	.00353
17	.651	518	2184	29,300	.192	26.3	1.38	2.82	.00396	.00347
18	.604	522	2181	27,000	.179	23.5	1.07	2.45	.00410	.00361
19	.590	512	2207	26,700	.171	21.5	.894	2.26	.00408	.00359
20	.562	518	2156	25,200	.168	19.3	.770	2.12	.00392	.00343
21	.507	508	2127	23,100	.152	16.5	.540	1.72	.00417	.00368
22	.478	512	2176	21,700	.141	14.8	.415	1.51	.00428	.00379
23	.420	518	2120	18,900	.128	11.7	.269	1.21	.00424	.00374
24	.344	512	2148	15,600	.103	7.85	.116	.790	.00437	.00387
25	.344	526	2116	15,300	.105	8.11	.127	.822	.00434	.00384
26	.288	517	2095	13,000	.089	5.67	.062	.574	.00436	.00386
27	.263	523	2081	11,700	.081	4.89	.045	.483	.00448	.00398
28	.255	524	2090	11,400	.079	4.78	.042	.455	.00465	.00415
29	.234	522	2089	10,400	.072	3.93	.029	.382	.00456	.00405
30	.224	514	2132	10,100	.067	3.43	.022	.337	.00451	.00401
31	.203	524	2082	9,100	.063	3.05	.017	.291	.00464	.00414
32	.202	522	2084	9,000	.063	2.91	.016	.287	.00450	.00400
33	.182	518	2081	8,200	.056	2.29	.010	.232	.00439	.00389
34	.162	522	2079	7,300	.050	2.00	.007	.185	.00482	.00432
35	.162	524	2081	7,200	.050	2.00	.007	.185	.00481	.00431
36	.111	524	2076	4,900	.035	1.04	.002	.086	.00534	.00484
37	.093	524	2074	4,100	.029	.749	.001	.061	.00552	.00502
38	.080	524	2074	3,600	.025	.650	.001	.046	.00635	.00585

[a] Corrected for momentum loss.
[b] Corrected for momentum, vena contracta, entrance, and exit losses.

[redacted]

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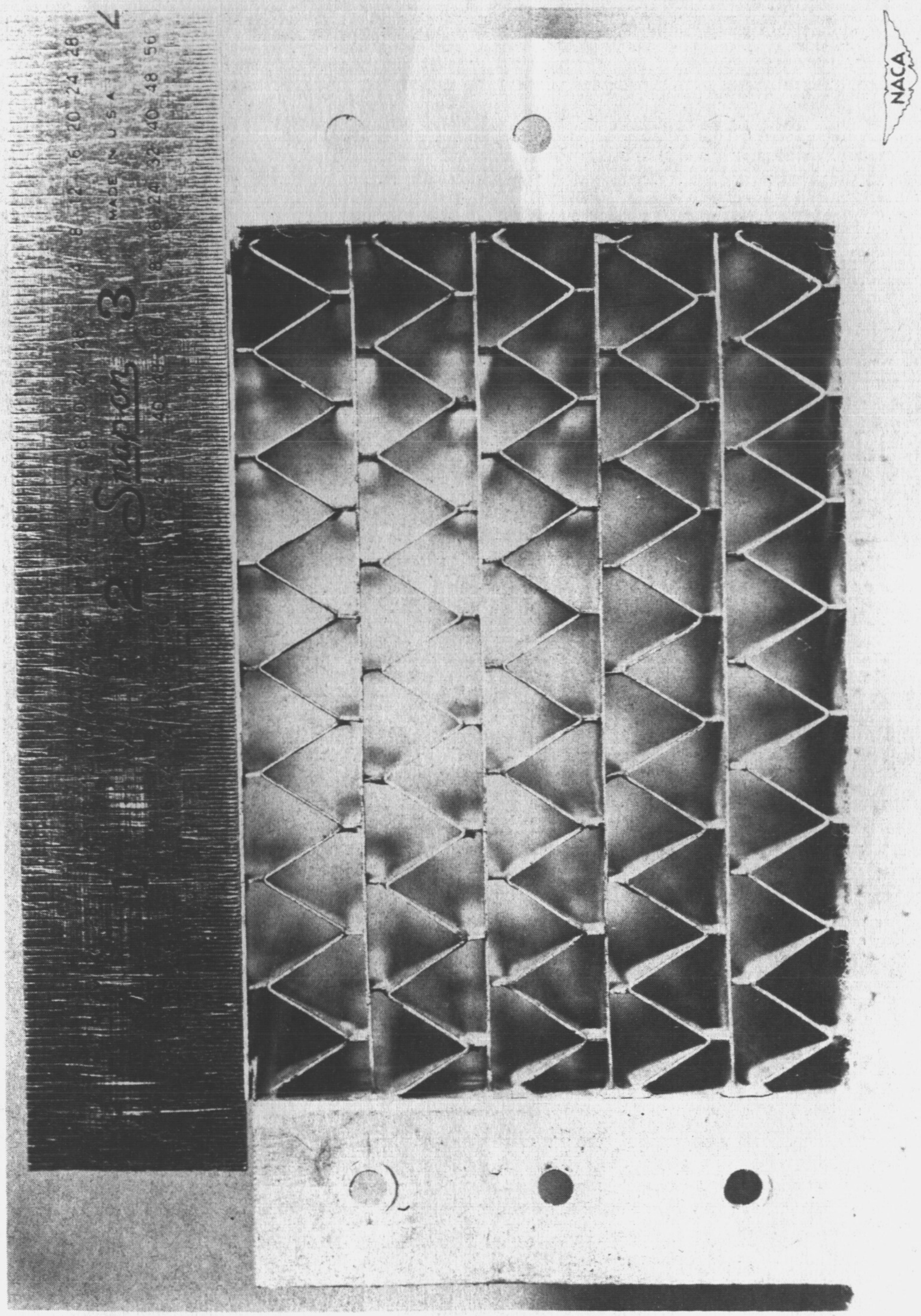
TABLE I - Concluded. MEASURED AND CALCULATED DATA FOR REACTOR SEGMENT ISOTHERMAL PRESSURE DROP TESTS

(b) Reactor segment number 10. Free-flow area, 0.0386 square feet; free flow factor, 0.90; equivalent diameter D_e, 0.0201 feet; length to diameter ratio L/D_e, 14.45.

Run	Air flow (lb/sec)	Inlet air temperature (°R)	Inlet air pressure (lb/sq ft abs)	Reynolds number	Inlet air Mach number	Measured pressure drop ΔP (lb/sq ft)	Calculated momentum pressure drop ΔP_m (lb/sq ft)	Calculated vena contracta pressure drop ΔP_{vc} (lb/sq ft)	Corrected half-friction factor[a] $\left(\frac{f}{2}\right)'$	Corrected half-friction factor[b] $\left(\frac{f}{2}\right)''$
39	1.643	520	2804	70,800	0.377	205	43.94	13.90	0.00502	0.00463
40	1.604	512	2779	70,100	.368	200	41.00	13.17	.00525	.00485
41	1.483	512	2680	64,800	.353	173	32.30	11.68	.00522	.00481
42	1.468	518	2643	63,500	.356	166	31.46	11.73	.00497	.00455
43	1.351	512	2570	59,000	.335	144	24.08	10.10	.00517	.00474
44	1.248	518	2491	54,000	.321	124	18.97	9.00	.00510	.00466
45	1.164	512	2439	50,800	.304	107	14.57	7.90	.00509	.00464
46	.991	518	2336	42,900	.272	82.1	8.82	6.05	.00524	.00478
47	.950	512	2315	41,500	.262	73.7	7.30	5.55	.00519	.00472
48	.749	512	2220	32,700	.215	46.2	3.06	3.59	.00521	.00473
49	.738	518	2214	31,900	.214	47.4	3.10	3.54	.00543	.00495
50	.466	512	2125	20,400	.140	18.8	.52	1.46	.00546	.00495
51	.247	528	2071	10,600	.077	6.40	.053	.43	.00637	.00585
52	.224	528	2068	9,600	.070	5.30	.037	.36	.00639	.00588
53	.179	528	2064	7,700	.056	3.38	.015	.23	.00639	.00588
54	.137	527	2060	5,900	.043	2.08	.005	.13	.00671	.00619
55	.088	527	2057	3,800	.028	1.04	.001	.06	.00811	.00759

[a] Corrected for momentum loss.

[b] Corrected for momentum, vena contracta, entrance, and exit losses.



(a) Number 5 reactor segment.

Figure 1. - Photographs of reactor-segment mockups.

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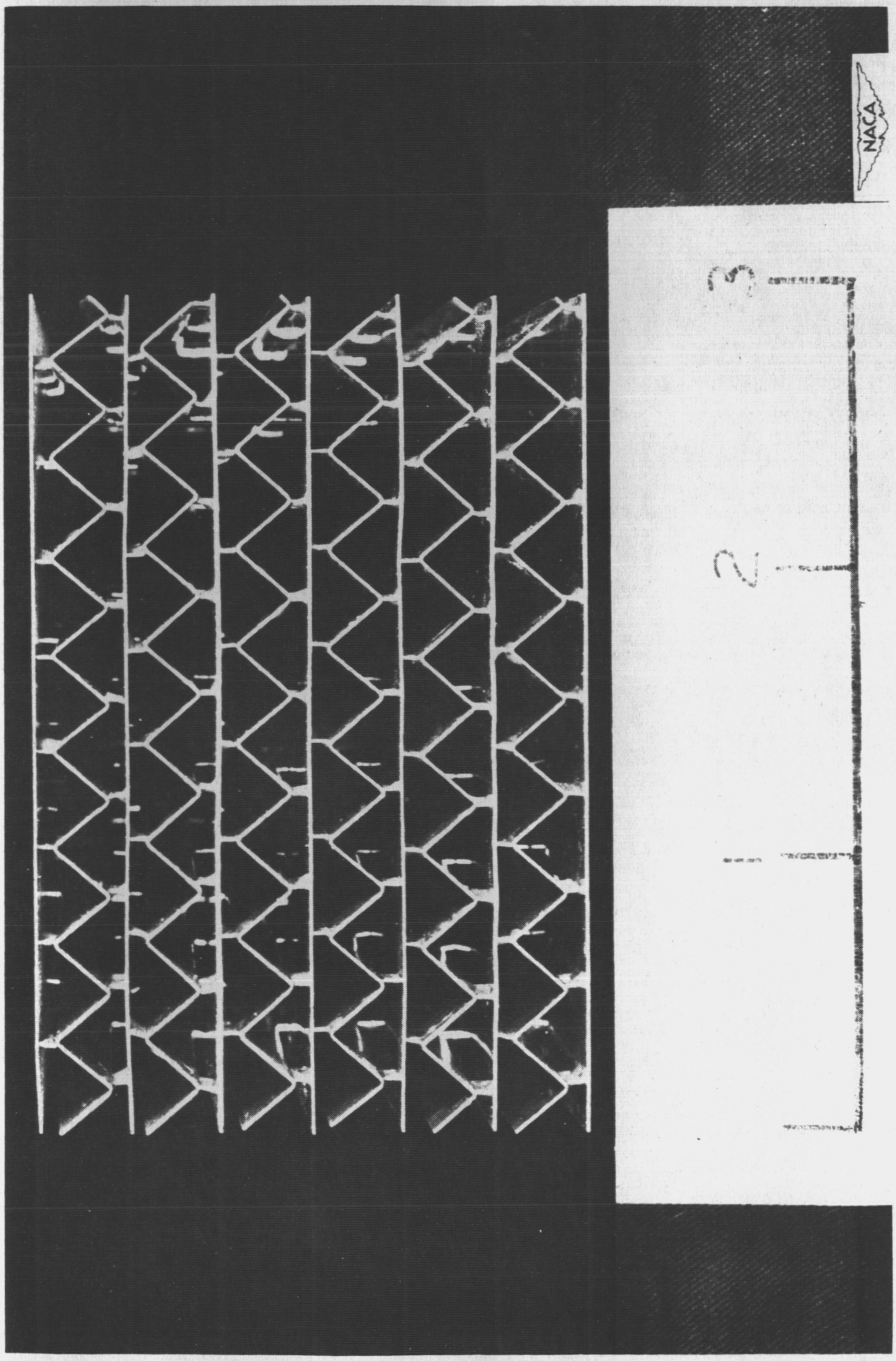
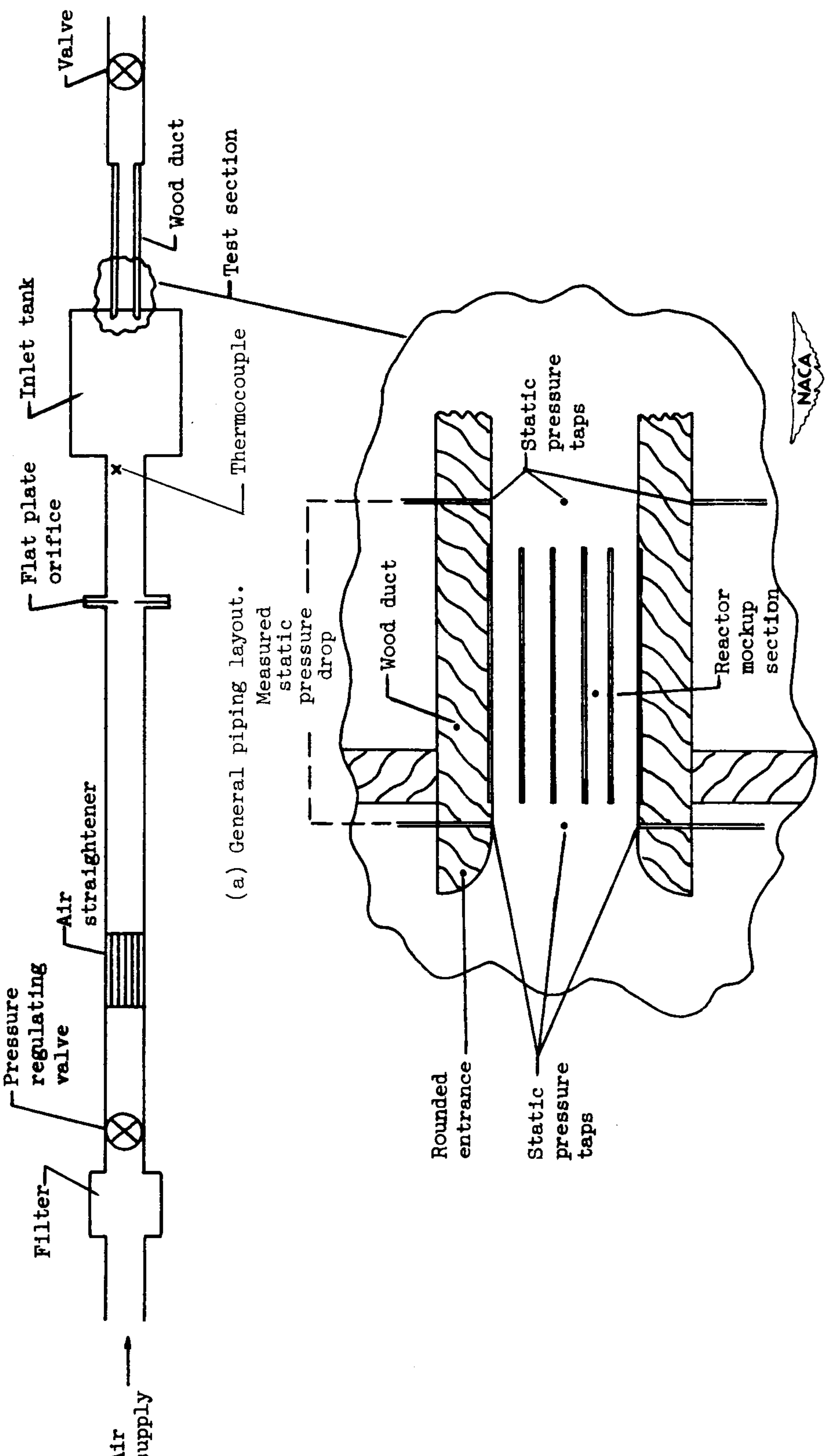


(b) Number 10 reactor segment.

Figure 1. - Concluded. Photographs of reactor-segment mockups.



(a) General piping layout.

(b) Installation and instrumentation of reactor segment.

Figure 2. - Schematic diagram of experimental setup.

[redacted]

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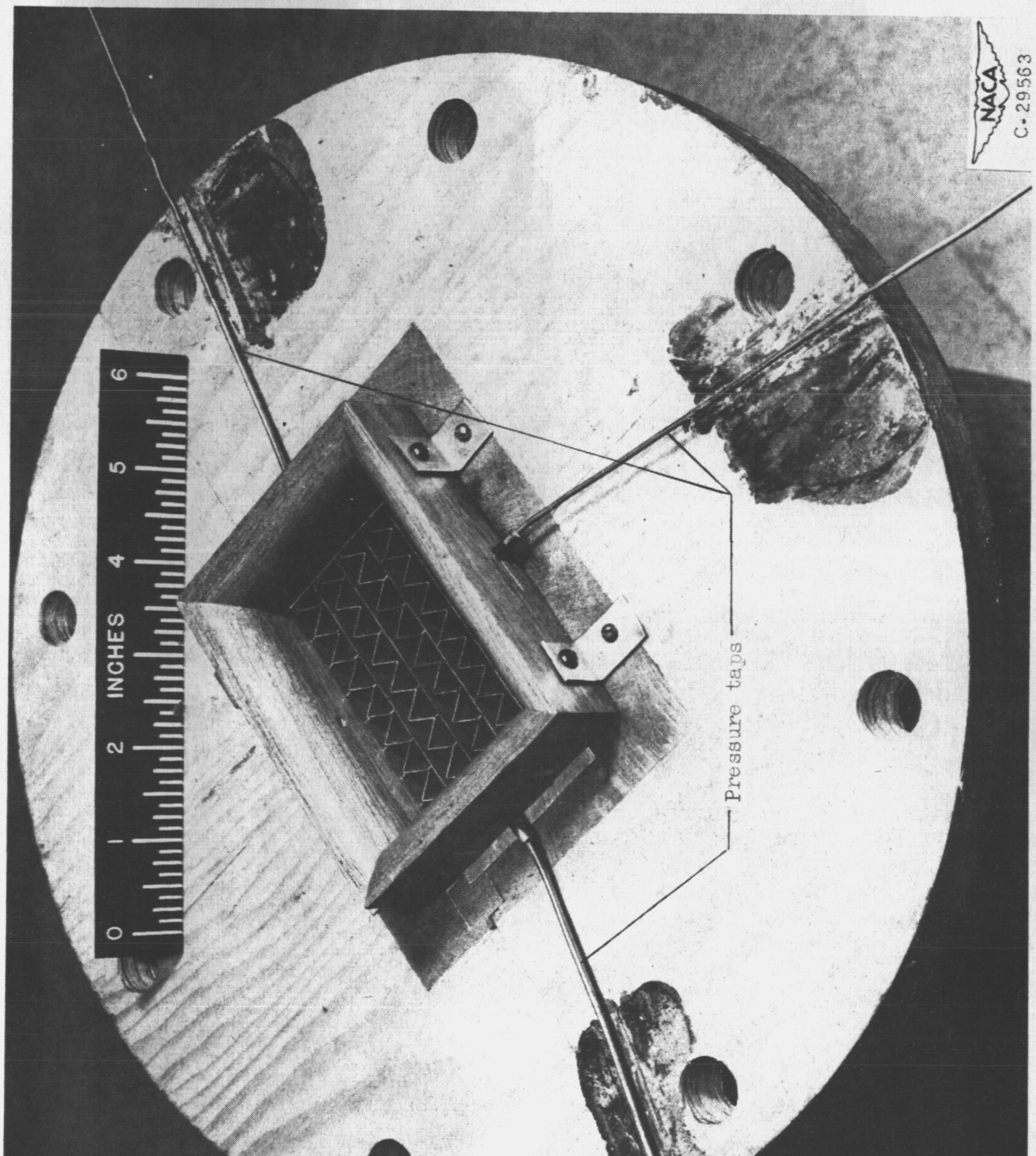

Figure 3. - Photograph showing installation of number 5 reactor segment, rounded entrance, and location of pressure taps.

[redacted]

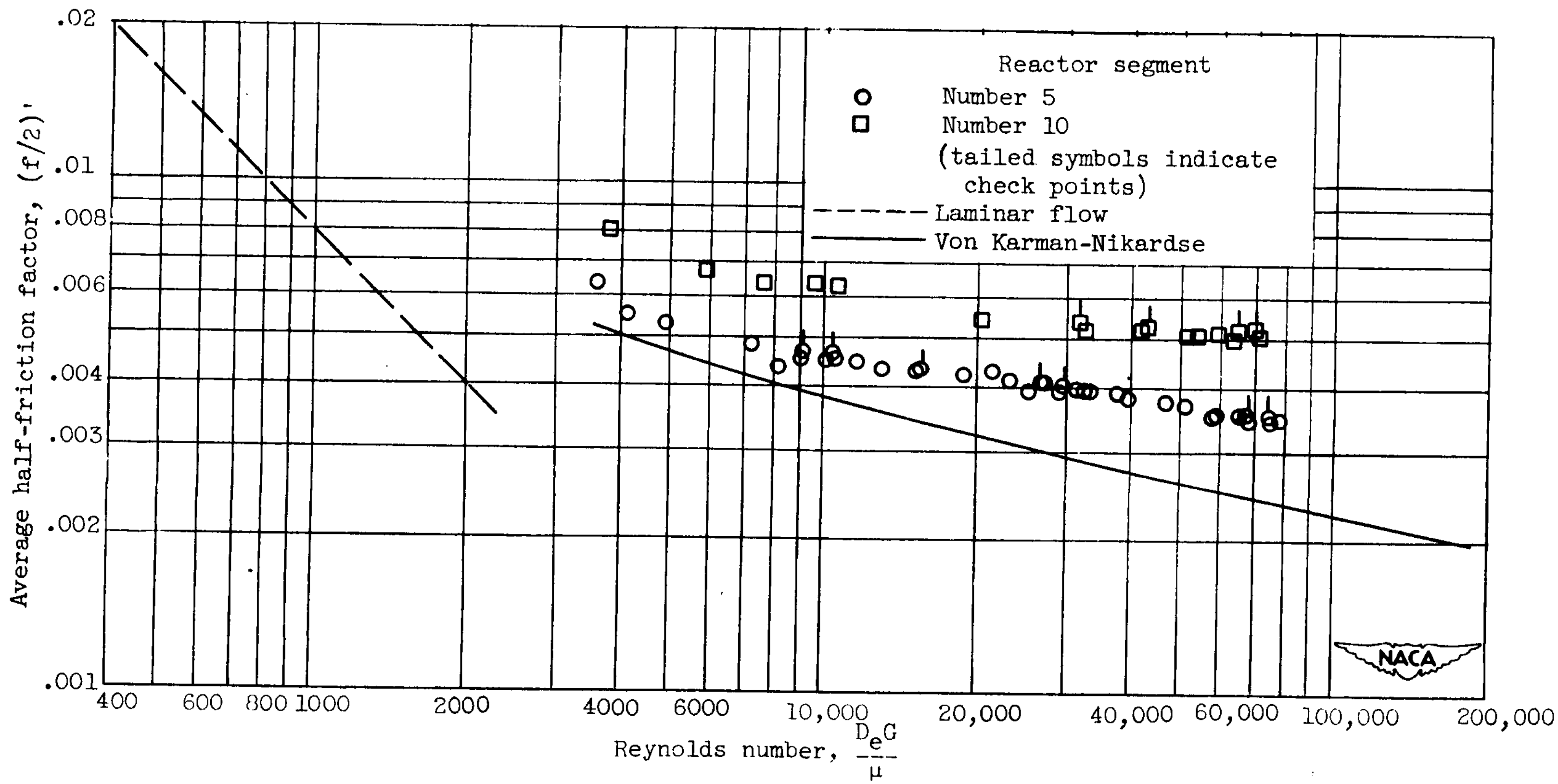

Figure 4. - Average half-friction factor $(f/2)'$ plotted against Reynolds number for reactor segments numbers 5 and 10. Friction factor corrected for momentum loss.

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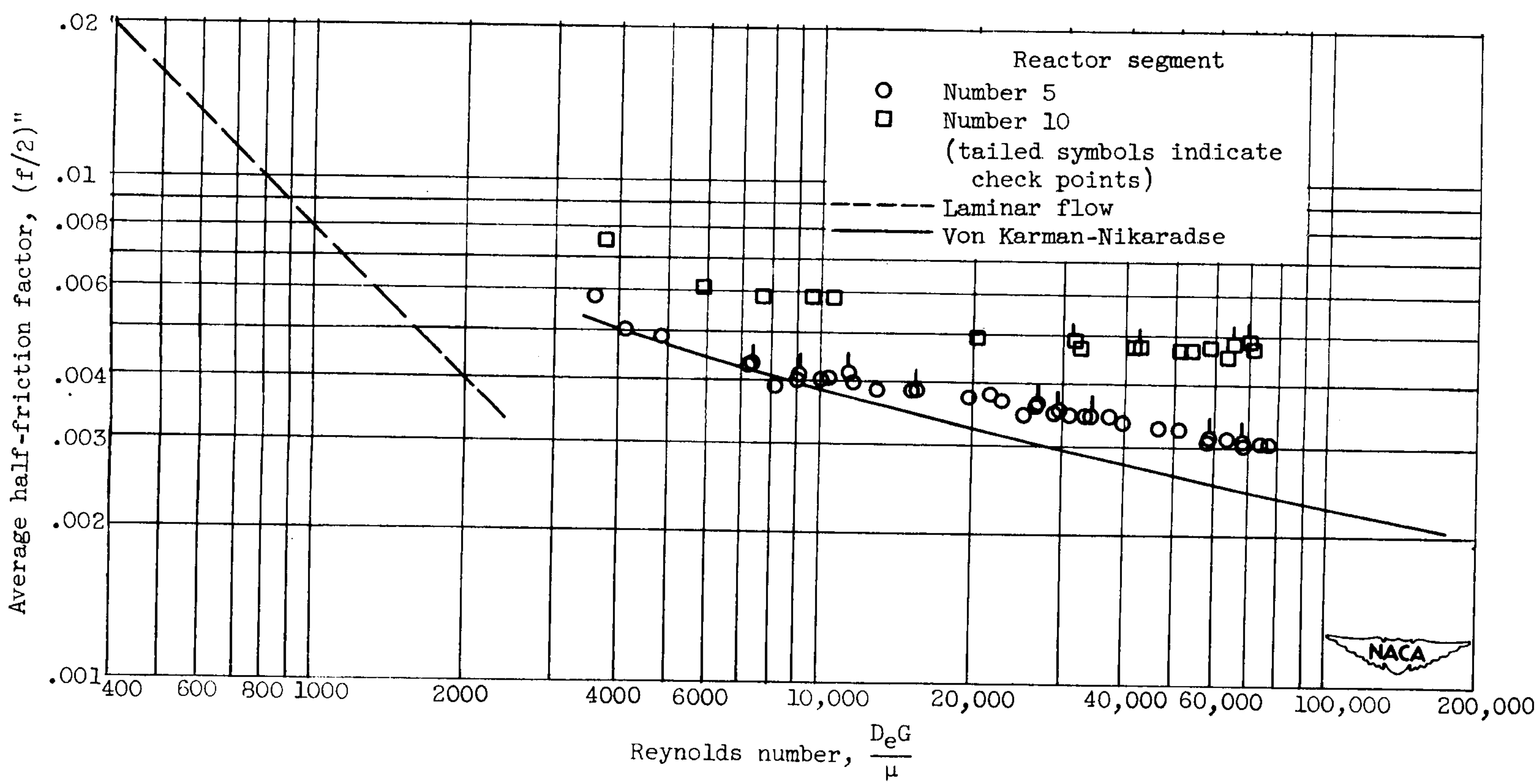

Figure 5. - Average half-friction factor (f/2)" plotted against Reynolds number for reactor segment numbers 5 and 10. Friction factor corrected for momentum, vena contracta, entrance, and exit losses.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

MEASUREMENTS OF PRESSURE DROP WITH NO HEAT ADDITION ON MOCKUP SEGMENTS OF THE GENERAL ELECTRIC AIR-COOLED AIRCRAFT REACTOR

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